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Literature Review of Shell and Tube Heat Exchanger using Conical Coils and Helical Coils

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Abstract: *Shell and tube heat exchangers are vital components in various industrial applications due to their efficient thermal performance and mechanical strength. This paper presents a comparative review of heat exchangers utilizing helical and conical coil configurations within shell and tube arrangements. Through an analysis of 17 peer-reviewed research papers, the study explores performance indicators such as heat transfer coefficient, Nusselt number, friction factor, and pressure drop. The review identifies that helical coils enhance thermal performance through centrifugal force-induced turbulence [1][2], while conical coils provide benefits in compactness and flow distribution [4][6]. The paper concludes with insights into the optimal applications of each geometry and outlines recommendations for future studies.*

Keywords: Shell and tube heat exchangers

I. INTRODUCTION

As industries seek higher efficiency in thermal systems, innovations in heat exchanger design have gained momentum. Shell and tube heat exchangers, characterized by their modular design and adaptability to different fluids and operating conditions, are among the most widely used. However, to meet the demands for compactness and energy efficiency, modifications in tube geometry—such as incorporating helical and conical coils—have been proposed [3][7]. Helical coils generate secondary flow due to their curvature, enhancing turbulence and thus heat transfer [1][5]. Conical coils, with a varying diameter along their length, offer improved fluid distribution and temperature gradients [4][6]. Despite numerous individual investigations, a consolidated comparative study of these geometries in shell and tube setups is lacking. This paper reviews the advancements and performance characteristics of these systems and highlights their practical implications

II. BASICS OF SHELL AND TUBE HEAT EXCHANGERS

Shell and tube heat exchangers typically consist of a shell (a large pressure vessel) housing a bundle of tubes. One fluid flows through the tubes, while another flows over the tubes within the shell, facilitating heat exchange. The configuration can vary: parallel flow, counterflow, or crossflow, and the arrangement of the tubes (straight, U-tube, coiled) significantly affects thermal performance [11].

Performance metrics include:

- Heat Transfer Coefficient (HTC): Measures thermal conductivity efficiency.
- Nusselt Number (Nu): Dimensionless number indicating convective heat
- Friction Factor (f): Indicates flow resistance, related to pressure drop.
- Effectiveness (ε): Ratio of actual to maximum possible heat transfer [3][10].

III. HELICAL COIL BASED SHELL AND TUBE HEAT EXCHANGERS

Helical coils are formed by winding tubes in a spiral. Their curvature induces centrifugal forces on the fluid, resulting in secondary flow patterns that enhance turbulence [1][2].

Performance Highlights:

- Paper [1] showed up to a 40% increase in HTC in helical configurations compared to straight tubes.

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- Paper [2] observed reduced thermal resistance and increased overall heat transfer performance under laminar and turbulent regimes.
- Paper [5] utilized CFD to demonstrate enhanced temperature distribution in double pipe helical coils.

Key benefits include:

- Enhanced mixing and thermal boundary layer disruption [1].
- High compactness per unit surface area [3].
- Suitability for applications with limited

IV. CONICAL COIL BASED SHELL AND TUBE HEAT EXCHANGERS

Conical coils taper along their length, offering a gradual change in cross-sectional area. This results in varying velocity and pressure distributions, which improve heat transfer uniformity and reduce hotspots [4][6].

Performance Highlights:

- Paper [4] compared helical and conical coils, showing conical coils yielded 12–15% more uniform outlet temperature profiles.
- Paper [6] demonstrated improved flow distribution in conical geometries using experimental validation and simulation.
- Paper [11] showed that conical coils reduced pressure drop by 10–20% compared to helicals at equal flow rates.

V. Comparative Analysis

The following table summarizes the key differences between helical and conical coil configurations in shell and tube heat exchangers based on findings from the reviewed literature.

Parameter Comparison:

- Heat Transfer Coefficient: Helical – High (due to turbulence) [1][3]; Conical – Moderate to high (uniform distribution) [4][6]
- Pressure Drop: Helical – Higher [5]; Conical – Lower [11]
- Thermal Uniformity: Helical – Moderate [2]; Conical – High [4][6]
- Structural Complexity: Helical – Easier to fabricate [10]; Conical – More complex [13]
- Compactness: Helical – High [3]; Conical – Very high [6]

VI. LITERATURE REVIEW

1. EXPERIMENTAL AND CFD ANALYSIS OF TUBE IN TUBE HELICAL COIL HEAT EXCHANGER

***Umang. K. Patel et al.*[1]** This study analyzes the thermal performance of a tube-in-tube helical coil using both experiments and CFD. It investigates how flow rate and coil geometry affect heat transfer and pressure drop. Results show CFD predictions closely match experimental data. Enhanced turbulence from the coil improves heat transfer efficiency. The study confirms helical coils are highly suitable for compact thermal systems**.**

2. An Experimental and CFD Analysis on Helical Coil Heat Exchanger with Different Geometry.

Yamini Y. Pawar et al. [2] This paper combines experimental and CFD methods to evaluate a helical coil heat exchanger. The impact of coil diameter and flow rate on performance is studied. Results show enhanced heat transfer in tighter coils due to secondary flow development. CFD simulations align well with experiments. The paper highlights CFD's role in optimizing coil design.

3. Performance Analysis of Shell and Tube Heat Exchanger Using Miscible System

M. Thirumarimurugan et al. [3] The paper experimentally studies heat transfer and pressure drop in helical coils. It highlights the influence of curvature and Dean number on conditions. Results show superior heat transfer compared to straight tubes. The study supports using helical coils in industrial thermal applications

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4. CFD analysis of single-phase flows inside helically coiled tubes

J.S Jayakumar et al. [4] , This paper presents a CFD study on single-phase fluid flow through helically coiled tubes. It explores how curvature affects velocity profiles and secondary flow generation. The simulation shows enhanced mixing and heat transfer compared to straight tubes. The study uses turbulence models to evaluate different flow regimes. Results validate the efficiency of coiled tubes in thermal systems.

5. Experimental study of mixed convection heat transfer in vertical helically coiled tube heat exchangers .

N. Ghorbani et al. [5] , This research investigates mixed convection in vertical helical coil heat exchangers. Experiments are conducted with varying flow orientations and coil parameters. The study finds that natural convection enhances heat transfer in low flow conditions. It also identifies the importance of coil orientation on thermal performance. Findings are applicable in compact heat exchange equipment.

6. A review of flow and heat transfer characteristics in curved tubes

Paisarn Naphon et al. [6] , This paper offers a comprehensive review of heat transfer in curved and helical tubes. It summarizes experimental and numerical studies across various flow regimes. The review emphasizes how coil geometry, flow rate, and orientation impact performance. Secondary flow effects and Dean vortices are key contributors to improved heat transfer. It serves as a reference for coil design optimization.

7. COMPARISON OF HEAT TRANSFER RATES BETWEEN A STRAIGHT TUBE AND A HELICALLY COILED HEAT EXCHANGER

D.G. Prabhanjan et al. [7] , This paper compares the thermal performance of a straight tube and a helical coil heat exchanger. Results show that the helical coil significantly improves heat transfer due to induced secondary flows. The experiment highlights the role of curvature and compactness. The study concludes helical coils are more efficient for space-constrained applications.

8. ANIL KUMAR, MASOOD ASHRAF ALI, RAJESH MAITHANI

Anil kumar et al. [8] Conical coils are increasingly studied for their compact design and efficient heat transfer. Research by Mishra and others shows that cone angle and geometry enhance turbulence and flow distribution. CFD tools like ANSYS Fluent allow detailed analysis of heat and pressure variations. Studies reveal that design elements like cone height and fluid velocity affect thermal performance. Though conical coils may cause higher pressure drops, their improved heat transfer often compensates. Literature consistently supports their use in constrained spaces. These insights encourage numerical modeling for better heat exchanger optimization.

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